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Tracer injection techniques in flowing surface water

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Residence time distributions for flowing water and reactive matter are commonly used integrated properties of the transport process for determining technical issues of water resource management and in eco-hydrological science. Two general issues for tracer techniques are that the concentration-vs-time relation following a tracer injection (the breakthrough curve) gives unique transport information in different parts of the curve and separation of hydromechanical and reactive mechanisms often require simultaneous tracer injections.

This presentation discusses evaluation methods for simultaneous tracer injections based on examples of tracer experiments in small rivers, streams and wetlands. Tritiated water is used as a practically inert substance to reflect the actual hydrodynamics, but other involved tracers are Cr(III)-51, P-32 and N-15.

Hydromechanical, in-stream dispersion is reflected as a symmetrical spreading of the spatial concentration distribution. This requires that the transport distance over water depth is larger than about five times the flow Peclet number. Transversal retention of both inert and reactive solutes is reflected in terms of the tail of the breakthrough curve. Especially, reactive solutes can have a substantial magnification of the tailing behaviour depending on reaction rates or partitioning coefficients. To accurately discriminate between the effects of reactions and hydromechanical mixing its is relevant to use simultaneous injections of inert and reactive tracers with a sequential or integrated evaluation procedure. As an example, the slope of the P-32 tailing is consistently smaller than that of a simultaneous tritium injection in Ekeby wetland, Eskilstuna. The same applies to N-15 injected in the same experiment, but nitrogen is affected also by a systematic loss due to denitrification.

Uptake in stream-bed sediments can be caused by a pumping effect arising when a variable pressure field is created on the stream bottom due to bed irregularities. The so-called pumping model provided good estimates of the storage in the hyporheic zone under different stream discharges and stream flow conditions along streams. Evaluations Hobøl River, Norway, and Säva Brook, Sweden, at two occasions in both stream indicate that the relative residence time in the hyporheic zone is linearly proportional to the squared Froude Number. The residence time is scaled with water depth and hydraulic conductivity of the bed.

The effect of such transient storage in e.g. the hyporheic zone gives rise to a tailing, but the breakthrough curve become increasingly symmetrical with Damköhler number. Such a symmetrical breakthrough can be erroneously taken as an effect of in-stream dispersion, even though this similarity is merely due to the physical analogy of various advection velocities over the transport cross-section, differential advection.